© 2017 IJSRSET | Volume 3 | Issue 8 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

# Electrochemical Machining of SS (Stainless Steel) 202

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## ABSTRACT

Electrochemical machining (ECM) is a non-traditional manufacturing process that can machine difficult-to-cut materials. In ECM, the material is removed by controlled electrochemical dissolution of an anodic workpiece in an electrochemical cell. ECM has extensive applications in automotive, petroleum, aerospace, textile, medical, and electronics industries. An in-house designed electrochemical cell was used for machining stainless steel 202 by ECM. The aim of this project is to study the material removal rate in an electrochemical machining process of SS 202 material. When the electrodes are immerged in the electrolyte the electrons are removed from the anode and deposited in the electrolytic tank. After taking the first reading the electrode immerged in the electrolyte again with high distance. So the electrons are removed from the anode for the given distance. The electrode distance also varied.
**Keywords:** Electrochemical machining, Anodic, Stainless Steel, Electrolyte.

## I. INTRODUCTION

The machining methods are classified into two types that are a traditional and non-traditional process. In that traditional machining process, the residual stress is induced during the machining of material. Like machining of material in the lathe. In that non-traditional machining operation, there is no residual stress. Electrochemical machining is the non-traditional machining process**.** Electrochemical machining (ECM) was developed to machine difficult-to-cut Materials and it is an anodic dissolution process based on the phenomenon of electrolysis, whose laws were established by Michael Faraday. In ECM, electrolytes serve as conductors of electricity. ECM offers a number of advantages over other machining methods and also has several disadvantages.

In electrochemical machining process, there is no residual stress induced in the workpiece. But another machining process like lathe the residual stress is induced. There is no tool wear; machining is done at low voltages compared to other processes with high metal removal rate; small dimensions can be controlled; hard conductive materials can be machined into complicated profiles; workpiece structure suffers no thermal damages; suitable for mass production work and low labor requirements.

### 1.1 Residual Stress

Residual stresses are stresses that remain in a solid material after the original cause of the stresses has been removed. Residual stress may be desirable or undesirable. For example, laser peening imparts deep beneficial compressive residual stresses into metal components such as turbine engine fan blades, and it is used in toughened glass to allow for large, thin, crack- and scratch-resistant glass displays on smartphones.

However, unintended residual stress in a designed structure may cause it to fail prematurely. Residual stresses can occur through a variety of mechanisms including inelastic (plastic) deformations, temperature gradients (during the thermal cycle) or structural changes (phase transformation). Heat from welding may cause localized expansion, which is taken up during welding by either the molten metal or the placement of parts being welded. When the finished weldment cools, some areas cool and contract more than others, leaving residual stresses. Another example occurs during semiconductor fabrication and microsystem fabrication when thin film materials with different thermal and crystalline properties are deposited sequentially under different process conditions. The stress variation through a stack of thin film materials can be very complex and can vary between compressive and tensile stresses from layer to layer.

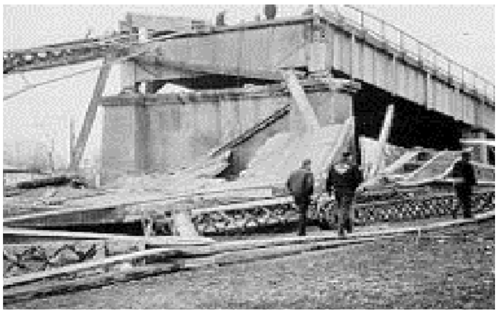

**Figure 1.** Residual Stress

The collapsed Silver Bridge, as seen from the Ohio side Castings may also have large residual stresses due to uneven cooling. Residual stress is often a cause of premature failure of critical components and was probably a factor in the collapse of the Silver Bridge in West Virginia, the United States in December 1967. The eyebar links were castings which showed high levels of residual stress, which is one eyebar, encouraged crack growth. Because the structure failed in less than a minute, 46 drivers and passengers in cars on the bridge at the time were killed as the suspended roadway fell into the river below.

### 1.2 Measurement Techniques

There are several techniques that are used to measure the residual stress. They can be classified as destructive and non-destructive methods. Mechanical methods or dissection uses the release of stress and its associated strain after doing a cut, hole or crack. A nonlinear elastic method as ultrasonic or magnetic techniques requires a reference sample. X-ray diffraction is a non-destructive method which allows the measurement of residual stress in isolated spots spaced distances as small as 100 micrometers. Neutron diffraction is an alternative non-destructive method which allows measurement of residual stress in isolated spots.

## II. METHODOLOGY

### 2.1 Experimental Setup

In ECM, the principles of electrolysis are used to remove metal from the workpieces. Faraday's Laws of electrolysis may be stated as: "the weight of substance produced during electrolysis is directly proportional to the current which passes the length of time of the electrolysis process and the equivalent weight of the material, which is deposited". The workpiece is made the anode and the tool is made the cathode. The electrolyte is filled in the beaker. As the power supply is switched on and the current flows through the circuit, electrons are removed from the surface atoms of the workpiece. These can get deposited in the electrolytic tank. After applying current, the electron will move towards the workpiece and also the settles down in the bottom. The tool is fed towards the workpiece automatically at a constant velocity to control the gap between the electrodes the tool face has the reverse shape of the desired workpiece. The sides of the tool are insulated to concentrate the metal removal action at the bottom face of the tool. The dissolved metal is carried away in the flowing electrolyte. The positive supply is supplied with Stainless Steel 202 material.

**Figure 2.** Experimental Setup

### 2.2 Components

- ✓ Power Supply
- ✓ Workpiece
- ✓ Tool
- ✓ Electrolyte and Electrolytic Tank

### 2.3 Power Supply

The range of voltage on machine 240 volts A.C. In the ECM method a constant voltage has to be maintained. At high current densities, the metal removal rate is high and at low current densities, the metal removal rate is low. In order to have a metal removal of the anode a sufficient amount of current has to be given. The Power supply is one of the main sources in our project. Because of the material removal rate is calculated depends on the amount of power supplied to the workpiece.

### 2.4 Work Piece

The workpiece is stainless steel 202.it is a general purpose stainless steel. Decreasing nickel content and increasing manganese results in weak corrosion resistance.

Length of the Stainless Steel 202 = 35.7cm

Diameter the Stainless Steel 202 = 0.8cm

**Figure 3.** Work Piece

### 2.5 Tool

The tool is iron. At increasing the carbon content of the iron will increase the tensile strength and iron hardness. The iron is suitable for the cathode and easily reacts with the anode.

Length of the iron = 15cm

The diameter of the iron = 1cm

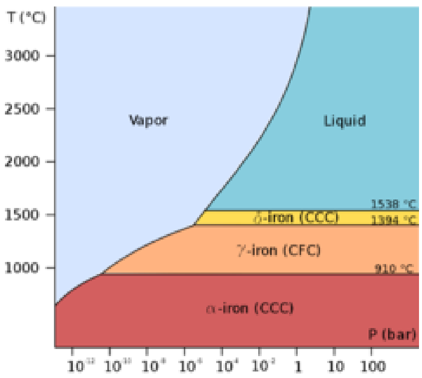


**Figure 4.** Low-Pressure Phase diagram of Iron

### 2.6 Electrolyte and Electrolytic Tank

The electrolyte is hydrochloric acid. Boiling, melting point, density, and ph depend on the concentration. It is a colorless and transparent liquid, highly corrosive, strong mineral acid. HCL is found naturally in gastric acid. The HCL is highly concentrated. In that process amount of HCL is 550ml.

Length of the Tank = 20 cm

Height of the Tank = 12.5 cm

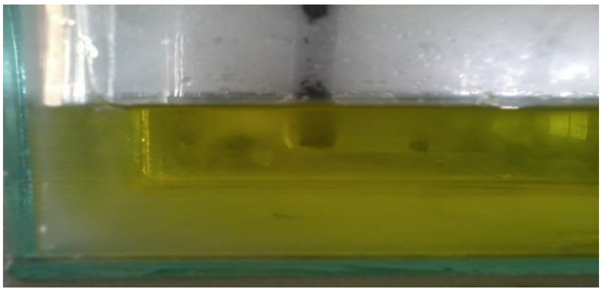

**Figure 5.** Electrolyte

**Figure 6.** Electrolytic Tank

### 2.7 Physical and Mechanical Properties

**Table 1.** Physical Properties

| S.No | Property | Unit | Value |
|---|---|---|---|
| 1 | Density | g / $cm^3$ | 7.80 |
| 2 | Thermal expansion | / k | $17 \times 10^{-6}$ |
| 3 | Modulus of Elasticity | GPa | 200 |
| 4 | Thermal Conductivity | W / mK | 15 |

**Table 2.** Mechanical Properties

| S.No | Property | Unit | Value |
|---|---|---|---|
| 1 | Proof Stress | MPa | 310 |
| 2 | Tensile Strength | MPa | 655 |
| 3 | Elongation | % | 40 |

## III. RESULT AND DISCUSSION

### 4.1 Electrochemical Machining Calculation for Constant Power Supply

The material removal rate is calculated by immersion depth of anode and cathode. 240 V current supply is input for the anode and cathode. The supply 240 V current is constant. The MRR is calculated after 15 minutes by using the formulas.

**Table 3**. Constant Power Supply for ECM (Depth)

| S.No | Voltage (Volts) | Time (Min) | Immersion Depth (Cm) | Material Removal rate ($Cm^3$ $Min^{-1}$) |
|---|---|---|---|---|
| 1. | 240 | 15 | 2.8 | 1.191 |
| 2. | 240 | 15 | 3.1 | 1.186 |
| 3. | 240 | 15 | 6.5 | 1.157 |

The material removal rate is calculated by immersion depth of anode and cathode. 240 V current supply is input for the anode and cathode. The supply 240 V current is constant. The MRR is calculated after 15 minutes by using the formulas.

**Table 4.** Constant Power Supply for ECM (Distance)

| S.No | Voltage (Volts) | Time (Min) | Immersion Depth (Cm) | Material Removal rate ($Cm^3$ $Min^{-1}$) |
|---|---|---|---|---|
| 1. | 240 | 15 | 12 | 1.191 |
| 2. | 240 | 15 | 8 | 1.186 |
| 3. | 240 | 15 | 6 | 1.157 |

When the immerged distance is increased the material removal rate decreased When the electrode distance is increased the material removal rate increased.

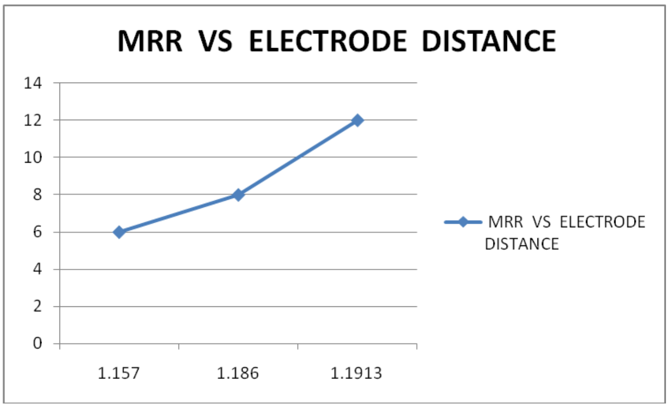


**Figure 7.** MRR Vs Electrode Distance

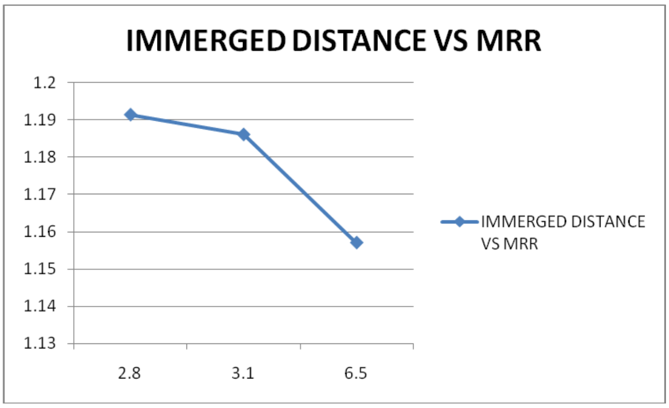


**Figure 8.** Immerged Distance Vs MRR

### 4.2 Electrochemical Machining Calculation for Variable Power Supply

The material removal rate is calculated by varying the power supply. The material removal rate is calculated up to 30V. The power should be varied every 10 V supply.

In this tabulation, the voltage is varied from 0-30V. At the same time, the immerged distance (2.8cm) and time (45min) will be constant. The voltage is increase means the material removal rate also increased.

**Table 5.** Different Voltage for ECM (2.8cm)

| S.No | Voltage (Volts) | Time (Min) | Immersion Depth (Cm) | Material Removal rate ($Cm^3$ $Min^{-1}$) |
|---|---|---|---|---|
| 1. | 10 | 45 | 2.8 | 0.129 |
| 2. | 20 | 45 | 2.8 | 0.167 |
| 3. | 30 | 45 | 2.8 | 0.216 |

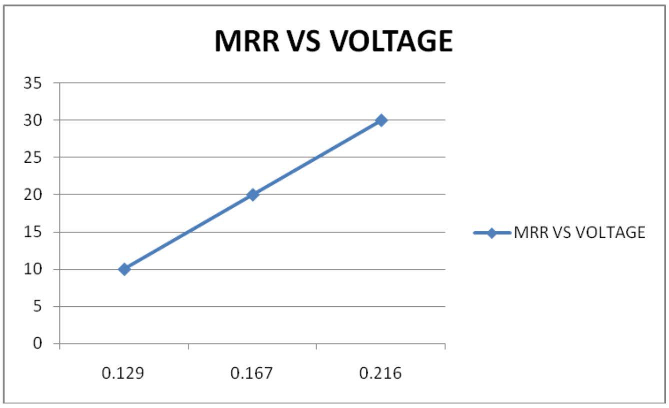


**Figure 9.** MRR Vs Voltage (2.8cm)

In this tabulation, the voltage is varied from 0-30V. At the same time, the immerged distance (3.1cm) and time (45min) will be constant.

**Table 6.** Different Voltage for ECM (3.1cm)

| **S.No** | **Voltage (Volts)** | **Time (Min)** | **Immersion Depth (Cm)** | **Material Removal rate ($Cm^3 Min^{-1}$)** |
|---|---|---|---|---|
| 1. | 10 | 45 | 3.1 | 0.118 |
| 2. | 20 | 45 | 3.1 | 0.156 |
| 3. | 30 | 45 | 3.1 | 0.194 |

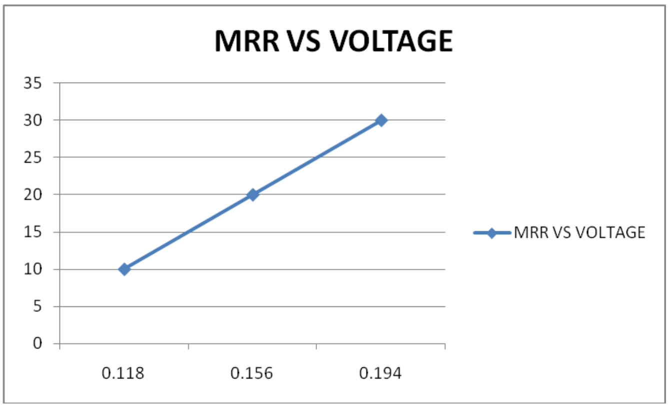


**Figure 10.** MRR Vs Voltage (3.1)

The applied voltage is increased means the material removal rate also increased. In the first graph the workpiece immerged distance is 2.8 cm and the second graph the workpiece immerged distance is 3.1 cm. In these two graphs, material removal rate value is taken in X-axis and current voltage is taken in Y-axis. So the graph between material removal rate vs voltage.

## IV. CONCLUSION

When the immersion depth is increased the material removal rate decreased and then the electrode distance is increased the material removal rate increased. the voltage increased means the material removal rate is increased. So the material removal rate is dependent upon the voltage immerged distance.

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